Novel Ultrathin Molecular Coating for Injection Molding Tools

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Motivation

Injection molding industry often employs **prototype molds** and mold inserts fabricated from Rapid Solidified Aluminum (RSA), specially for cutting edge mold applications in where quality is paramount, namely optics, photonics and microfludics. Prototypes are also used for verification of mold filling.

Aluminum molds have substantially reduced lead time (days instead of weeks), lower manufacturing cost (30%) and excellent surface finish. Surface roughness (RMS) is often below 5 nm after diamond machining. Conventional coating with thickness of few microns may ruin small features.

We proposed perfluorinated trichloro-silane (FDTS) coating, realized it and tested stability in challenging conditions of injection molding, up to 200MPa and 250°C.

Method

FTDS monolayer coating was deposited in comercial MVD 100 system from Applied Microstructures using relevant multilayer recipe in presence water vapor at approximately 50°C.

Samples have been characterized by XPS and by Sessile Drop shape analysis on at least 3 locations of each sample at least 10 mm apart to account for possible surface heterogeneity.

Wear stability testing

- **Pristine** (uncoated control sample)
- **Coated** (fresh FDTS coating)
- **Post Injection molding** (500+ IM cycles with polystyrene (PS) and proprietary yellow ABS material)

Temporal stability testing
More than 7 months at ambient conditions prior to testing of post IM.

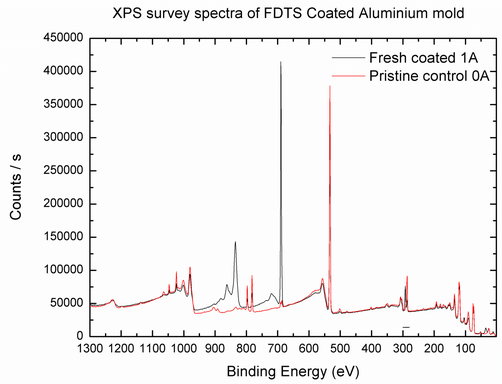

Figure 1. XPS Survey spectra shows distinct F1*s* peak near 690 eV.

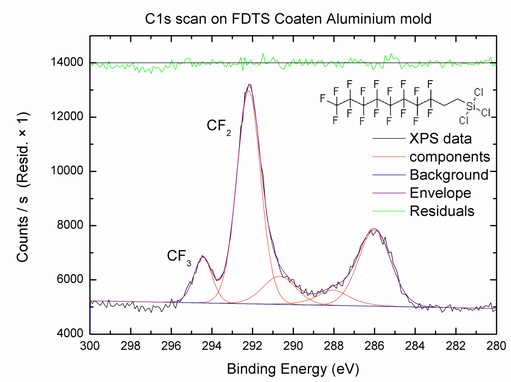

Figure 2. C1*s* spectrum, where the ratio of peaks corresponding to CF_2 to CF_3 is 6.89. This serves as a specific fingerprint of FDTS coating presence. Structure of a FDTS molecule is shown as insert.

Name	Peak BE	FWHM eV	At. %
O1s	531.04	3.34	44.6
Al2p	72.32	5.11	34.19
C1s	284.44	3.17	19.44
F1s	685.07	3.83	1.77

Name	Peak BE	FWHM eV	At. %
O1s	533.14	3.21	31.62
Al2p	75.54	5.09	26.78
C1s	292.17	2.72	11.78
F1s	689.76	2.95	29.82

Name	Peak BE	FWHM eV	At. %
O1s	534.01	3.23	29.25
Al2p	75.88	4.76	19.13
C1s	287.17	2.98	24.03
F1s	690.77	2.56	27.59

Tables 1-3. Pristine, Coated and Post IM surfaces (top to bottom).

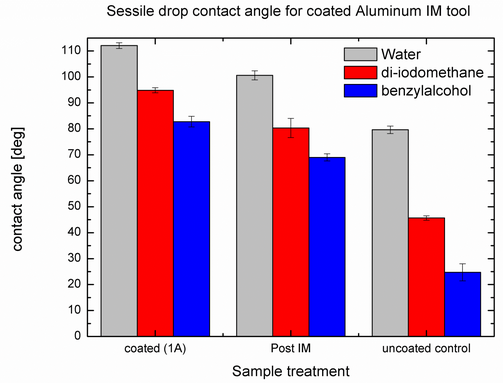

Figure 3. Contact Angle measurement results for different surface treatment and fluids.

Conclusion

XPS spectral survey data confidently shows presence of Fluorine in both coated and post IM samples and Carbon 1*s* spectra identify coating to be expected molecule. Covalently bonded coating molecules do prevail injection molding.

Surface energy is reduced 3 times by presented coating and this modification prevails over harsh IM cycling with enormous pressure and temperature loading. Temporal stability is excellent as well.

Predicted coating lifetime is at least 7700 shots and we expect much higher number. Deposition from gas phase is uncomplicated and affordable, suitable for prototype mold manufacturing workshops. Mold can be easily striped and re-coated if needed. This coating which is ultrathin, covalently bonded monolayer is reasonably durable, affordable, scalable to production and detectable on surface. It is especially suitable for rapid mold prototyping and mold geometry testing.

Presented result is commercially relevant, therefore nationally & internationally protected. It is available for licensing. Feel free to contact author for details.

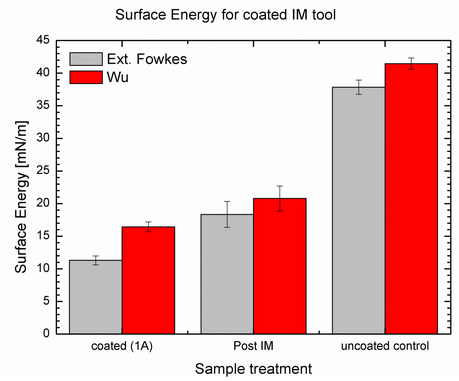

Figure 4. Aluminum Mold Surface Energy decreases ~3 times and stays decreased even after injection molding as shown above, where SE was calculated using different methods.

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